ously in and upward. Lightning was not especially noticeable until the junction of the two tornadoes at the mouth of Otter Creek, then it was continuous and blinding.

During its passage through Greer County the rain and hail occurred after the tornado passed, but it was both preceded and followed by rain in its passage through Kiowa County.

The noise of the tornado was heard over a radius of twelve miles from its path, as a grinding, crashing roar that was indescribable.

The tornado path covered about 65 miles in length; the tornado was first observed at about 6:45 p. m., and last observed at 8:45 p. m., thus having an average forward movement of 30 miles per hour.

A peculiar feature noted and spoken of by a number of persons during the progress of the tornado over the storm caves in which they had sought refuge, was the drawing or uplifting force exerted upon them. They stated that while under the center of the storm it seemed that their bodies had lost weight and that they were gradually being drawn out of their places of refuge and had no will to resist the movement. In each case the storm door fastenings were broken loose and the doors thrown open for a short period of time, and then thrown back into position.

At the residence of Mr. G. E. Colville, a young man standing in front of the house, watching the approach of the tornado, stated that the first effect of its influence was the sudden uplifting of five bales of cotton, standing about 60 feet in front of him, to a height of about six feet above the ground, after which they were thrown back on end; then one bale was picked up and it passed through the air over his head striking the corner of the house to his rear; at the same time he was thrown forward to the ground, where, catching hold of the trunk of a small tree, he lay until the tornado had passed. While on the ground he saw the house gradually pushed backward about 30 feet, and then instantaneously go to pieces; at that instant the windmill close by was dashed to the ground. Mrs. Colville, who was in the house, escaped with only a few bruises, while the young man was uninjured. The house was about 200 yards from the center of the tornado track.

All houses and buildings along the path of the tornado, in the country, were completely demolished, and the loss to buildings amounts to $20,000. Where the tornado crossed the wire fences, the center was marked by the wires being cleanly cut through as though pliers had been used, the breaks being directly over each other in four-strand fences. In some instances, a dozen posts were pulled out of the ground, and thrown forward, the united wires forming a half circle on the ground.

## STUDIES ON THE DIURNAL PERIODS IN THE LOWER STRATA OF THE ATMOSPHERE.

By Prof. FRANK H. BIGELOW.

### VI.—GENERAL REVIEW OF THE STATUS OF COSMICAL METEOROLOGY.

#### COSMICAL METEOROLOGY.

A great advance is taking place in the science of meteorology, and this has been brought about during the past fifteen years. It has been due to two causes, the growth of modern physics, and the extension of observations into the strata of atmosphere high above the ground. The new theories of the constitution of matter, in which the emphasis is laid upon the electrical nature of the ultimate units of which atoms and molecules are constructed, and the transmission of energy in ether waves across great distances, have disposed the scientific world to examine old conclusions from a very different point of view.

(1) In 1890 the high temperature of the sun seemed to justify its exclusion from the class of magnetized spheres, and thus to separate it from the group containing the earth. Now, however, there are numerous arguments which make it necessary to reconsider that view, and to admit that the sun is probably a highly magnetized sphere which sustains a magnetic field embracing the earth in its action.

(2) Then the radiation from the sun was considered a constant quantity, but now, there are so many lines of converging evidence to show this may not be true, that the subject has become one of serious investigation, and the belief is widespread that the sun is a variable star transmitting its energy to the earth in such ways as to produce synchronous changes in its meteorological and climatic conditions.

(3) In those days the theories of the general circulation of the atmosphere, as formulated by Ferrel, were generally considered to be correct, but the explorations of the atmosphere, by means of theodolites, nephoscopes, kites, and balloons have seriously discredited all except the central idea.

(4) In the same way, the Ferrel theory as well as the Oberbeck theory of the circulation of the air in local cyclones and anticyclones, have both become obsolete, and a new type of vortex is being considered as applicable to them.

It is evident that a reconstruction of ideas is in order all along the line, and that meteorology is passing through a transition period in its development. The general outcome is to raise meteorology from a subject which was the peculiar property of the climatologist and the forecaster into one of vital interest in cosmical science, and, indeed, one which is essential to the progress of astrophysical astronomy. This change from an empirical and statistical basis, requiring merely clerical functions in those practising the art, to a plan of operations involving the highest ranges of astronomy, mathematics, and physics in its students, is one of the most hopeful signs of the times. Meteorology has really languished for the lack of a demand for high grade scholarship, but the knowledge that the observations of pressure, temperature, vapor tension, and vectors of motion in the earth's atmosphere have an astronomical value, will, of course, facilitate the introduction of methods of precision in the observations and in the computations leading to a discussion of the results.

The research that is bringing about this change in meteorology has been one of extraordinary difficulty for two or three reasons. In the first place, by the very nature of the case, meteorology must depend largely upon handling great masses of data, at least till a higher stage of classification and unification of the laws has been attained, because the action of the several elements differs greatly from one station to another over the earth, and each station must be considered on its own merits. In astronomy, on the other hand, a ready concentration of observations, made in various places upon the same celestial object, is practicable, and this coordination leads more rapidly to a final set of constants and formulæ. The astronomical ephemeris, embracing the positions of the sun, moon, planets, and stars, with their characteristic phenomena, are, thus, readily made up, and by successive comparisons between predicted and observed places a progressive accuracy has been developed. Meteorology has not yet attained the dignity of the most elementary kind of ephemeris, but has been content with striking a rough mean or normal from a large mass of crude observations. This method has no doubt been sufficient for climatological statistics, and for such forecasts as have been attempted during the past, but with the entrance of cosmical problems into the field of work that sort of procedure is entirely inadequate.

#### A METEOROLOGICAL EPHEMERIS.

As already mentioned, the first line of improvement, having in view the ultimate construction of a true meteorological ephemeris, is a careful discussion of the existing data. An examination of the available observations in the various portions of the earth, convinced me several years ago that for cosmical meteorology they are well nigh valueless in their present state. There has been an incessant change in the conditions under which the observations were made, following the exigencies of administration, or in consequence of the lack of scientific purpose and method in conducting the reductions. Thus, the hours of observation have been changed, and this has broken up the homogeneity of the series; the elevation of the station has been frequently altered; the exposure of the instruments to the weather has been modified, often radically, by the growth of our large cities; hence it is that a pure series of data extending over several years is not a common feature of any meteorological service. The ephemeris of this science must take account of a list of natural phenomena different from that found in the astronomical almanacs, namely, the pressure, the temperature, the vapor tension, and the wind vectors in the atmosphere of the earth, at the least; the frequency of the spots, the faculæ, the prominences on the sun; the intensity of the lines in the spectrum, distinguishing those of solar from those of terrestrial origin; the relative absorption of the radiation in the solar and the terrestrial envelopes, respectively; the strength of the electric and the magnetic fields in the earth's atmosphere, including the auroras, the ionization, the electric potential, and the coefficient of dissipation. In all these cases, for the construction of an ephemeris, it is not sufficient to strike a mean value from a series of observations extending over a number of years, where the individual years are not homogeneous one with the others. What we want is a series of correct yearly and monthly residuals relative to a central normal or mean value, wherein it is certain that the apparent variations from year to year are not due to faulty instruments and inadequate modes of observing, nor to incorrect and insufficient methods of computing. There is an immense mass of meteorological data which in its present state has no value for a cosmical science, because the accidental errors, that is those which can be controlled and ought to be eliminated in forming a truly homogeneous series, are larger than the residuals which can correctly be attributed to the variable solar action. *The margin of variability induced at the earth by the unsteady energy of the sun is quite narrow, and there is nothing to be squandered by poor workmanship if any useful results are to be accomplished in practical meteorology.* There is nothing scientific in attributing to the sun's action those changes which pertain to the inaccurate observer or to bad methods of working the the instruments, nor is there any justification for comparing good solar observations with bad meteorological observations. If cosmical meteorology is to be established then all rough and ready methods must be abandoned, and the work of computing and discussing the data must be placed in the hands of physicists and astrophysicists who possess scientific instincts and training. It is only by acquiring long series of accurate residuals in all the elements enumerated above, that is to say exact values for each month and year at the selected standard stations, that a suitable ephemeris can be constructed. Upon the successful accomplishment of this purpose depends the establishment of cosmical meteorology and the detection of the laws controlling the many interrelated forces which culminate in weather and climatic conditions. I maintain that the seasonal and yearly changes in climate, which each country experiences, depend upon the variable output of the solar energy, as recorded in the circulation of the sun's atmosphere and in our own atmosphere, and the sequence of these variations is a proper subject for scientific examination. This work in one sense is common to the entire earth, and yet each country has its own climatic effect to be accounted for in the general integration. No country can transfer its task to another, and each has enough to do to take care of its own observations. To some extent international cooperation is desireable and practicable, but on the whole each climatic region must work out the problem for itself. There is a common solar-terrestrial circulation which flows throughout the entire cosmical system, yet each country has a pulse of its own, and this must be discovered and analyzed before there can be any expectation of establishing an efficient seasonal meteorology.



THE PRESENT STATUS OF THE REDUCTIONS.

My own work has for many years been concerned in reducing the crude meteorological data for the sun, the earth generally, and especially for the United States, into standard conditions, from which the first approximately correct residuals may be attained. The task has been far beyond my power, with the resources at command, and the work is not yet finished. Thus, (1) from 1878 to 1893 the magnetic vectors have been properly computed, but they had to be extended by graphic methods back to 1841 and forward to 1903 in order to get even a glance at the fundamental law. (2) The diurnal magnetic vectors were worked out for 30 stations and they are in good order. Neither of these works have been published. (3) The pressures for the United States, 1873 to the present time, have been thoroughly recomputed and they are in a satisfactory state. (4) The temperatures are in process of reconstruction, but the task is much more difficult than in the case of the pressures and the work is not finished. (5) The reductions of the vapor tensions are being carried along with that of the temperatures, and they are only partly completed. There have never been any vapor tension normals available in the United States. (6) All the data of atmospheric electricity are in a chaotic state and need complete revision. (7) The ephemeris of relative sun-spot numbers is in good condition in consequence of the work of Wolfer. (8) The prominences and faculæ have been thoroughly discussed by me, but the results have not been published. (9) In the variation of the spectrum lines, and in the variability of the solar radiation as disclosed by the actinometer and bolometer, it has only quite recently been recognized that there is a real problem to be worked out, and we have as yet no true series of observations to classify.

It is evident from this statement that for the United States, where this plan of reducing the observations has been systematically in operation for several years, there remains much computing to be done before we can begin to put our meteorological ephemeris together. Until this is accomplished there can be no attempt to take up the problem of seasonal forecasting, and the quicker this work is finished the better for science in all its astrophysical branches. For it is quite probable, judging from the exposition contained in the preceding papers of this series, that there exists a beautiful yet sensitive network of forces reaching from the sun to the surface of the earth, by which we can learn to read the signs of the climate, and we may hope to be able to learn to forecast it somewhat in advance by a natural system of extrapolation. In the midst of this concatenation of forces the terrestrial magnetic field stands out as the best unifier or integrator. It is the most sensitive and delicate pulse which we possess, having one throb in the solar mass, and the other in its synchronism with the earth's meteorological elements. We shall, then, in our further discussions, use this magnetic system as the proper one about which to group all the other elements which are correlated in this great solar–terrestrial complex.

THE SUN AS A MAGNETIZED SPHERE.

The radical change, gradually brought about by numerous physical researches in our ideas regarding the ultimate constitution of matter, by which we conceive of atoms as composed of dynamic structures of balanced rapidly rotating electric charges, has, also, materially modified the attitude of mind in which we approach the problem of the magnetization of large rotating heavenly bodies. When the atoms were regarded as hard, highly elastic, nonelectrical, and nonmagnetic spheres moving by the laws of kinetic energy in straight paths, except for the effect of collisions, it was of course difficult to prove that the sun could be magnetic of itself at the high prevailing temperature. But if the integrated forces are to be derived from electric charges in very rapid motion, and this seems to be the case, then magnetic fields are essential to the existence of every kind of matter whether in large or in small masses. Under ordinary conditions the primitive motions of the ionic charges are highly disorganized, since the motions are in every conceivable plane, and the molar or large masses do not show any outside field of force. It is, however, only necessary to organize these ionic motions relative to one plane, that is, to polarize their orbits, in order to produce a common magnetization within the mass and magnetic field outside this body. When a steel magnet is subjected to heat the field is destroyed, simply because the minor magnets, as of the atoms and molecules temporarily oriented to one axis, have been made disordered by the higher class of collisions which has been induced by the increase of the temperature. This experiment, however, by no means exhausts the natural conditions of the problem. In a rotating body like the sun the angular velocity induces a deflecting force at right-angles to the momentary motion, of every particle, $l = \omega\, q \cos \theta$, depending on the angular velocity, and polar distance velocity in any linear direction. When $q$ is great, and in the case of the negative ions combined in the atom, it may approach the velocity of light, $l$ is also a comparatively large force, so that a tendency to run into vortex motion is ever in operation. The entire mass of the sun, by the general laws of motion, also is evidently organized as a great vortex about the axis of rotation, and these two impulses doubtless tend to polarize the motions of the individual atomic ions in planes perpendicular to this axis, or to produce magnetization nearly parallel to the axis of rotation. Since the movement of the negative ions is in excess of that of the positive ions, the resultant magnetic field will be due to this excess of the action of negative electric charges above the positive charges, since for a common direction of gyration the positive and negative charges produce oppositely directed magnetic field. Finally, if the negative charges, in the atomic conflict, tend to escape from their electric bonds and to roam in disregard of any structure, then these negative charges may well tend to accumulate as an electrostatic layer on the surface of the sphere. At least the negative body-charge may, as a whole, be located farther from the center of the sphere than the positive body-charge, and this will produce internal magnetization and surface electrostatic charge, such as the earth possesses, and such as we have evidence to indicate that the sun also possesses. This dynamic view of mine comes to the same result as the static theory explained by Sutherland.[1] With this introduction I shall merely mention various results obtained in my researches, which are at least circumstantial evidence that the sun is a highly organized magnetic body, and that the numerous variations in its internal action constitute the causes for the observed changes in the external magnetic field.

(1) The polar rays of the corona, at least at minimum, conform to the normal lines of magnetic force on a sphere seen in projection, and concentrated in a ruffle at some distance from the pole.

(2) The ions in the solar atmosphere are luminous along rays of magnetic force.

(3) The coronal poles are located asymmetrically with respect to the axis of rotation, and persist from one eclipse to another in the same relative positions.

(4) The sun's external magnetic field, as measured at the earth, is so arranged that it has greater intensity in some solar longitudes than in others.

(5) By using large masses of observational material, the typical curve, attributed to difference in solar output in longitude and depending for its existence upon the structure of the sun's nucleus, has been found to be reproduced approximately, in the distribution of the sun spots and prominences in longitude, in the terrestrial magnetic elements, the electric field, the barometric pressures, the temperatures, and the local cyclonic movements in the United States.

(6) There is evidence that the periods of rotation in the higher latitudes of the sun fluctuate about a mean value synchronously with the external energy variations, showing that the entire external system is a direct effect of the forces producing at the same time the interior circulation in the mass of the sun.

(7) The inference is that the sun's magnetic field embraces the earth, and reaches it in lines perpendicular to the ecliptic, falling upon the polar regions of the earth along the planes of the magnetic meridians.

THE RADIATIONS OF THE SUN.

The electromagnetic radiation of the sun transports to the earth the other kind of energy which is concerned in the temperature excess prevailing in the Tropics over that in the polar zones, and produces the observed general and local cyclonic circulations. The coronal rays, especially in the equatorial belts of the sun, indicate that there are other forces in operation in the neighborhood of the photosphere besides those already mentioned.

(1) The spreading of the great streamers away from the plane of the ecliptic suggest an electrostatic repulsion.

(2) The streams of ions, under the action of the mechanical pressure of light, move not in radial lines, but in curves as determined by the additional magnetic and electrostatic forces prevailing in the surrounding space.

(3) It is impossible to assert that enough ions reach the upper strata of the earth's atmosphere to produce the observed variations of the terrestrial-magnetic and electric fields as registered in the lower strata, and it is not probable that this is the fact.

(4) This radial radiation of the photosphere may be to some extent variable in its output, and so produce seasonal climatic temperature and weather variations synchronous with it, as registered in the pressures and temperatures in different regions of the earth.

(5) The normal equilibrium of the earth's atmosphere is probably disturbed frequently, from day to day and hour to hour, by the interplay of this complex system of correlated forces.

THE METEOROLOGICAL EFFECTS OF THE SOLAR ENERGY.

The problem of discussing the effects of the solar radiation upon the magnetic and the electrical fields of the earth's atmosphere, and their relations to the meteorological elements, has been greatly simplified by the results of the research contained in the first four papers of this series. It has been shown that a different correlation of the quantities in consideration can be made and that in this way the intractable conditions which have so long puzzled scientists are decidedly ameliorated.

(1) The fact that there is no one synchronism common to the entire earth between solar and terrestrial causes and effects, has been explained by showing that the temperatures synchronize directly in the tropical zones, but only inversely in the temperate zones, in consequence of the inverting effects of the general circulation; and that while the pressures in the Eastern Hemisphere respond directly to the solar inpulse, they surge inversely to it in the Western Hemisphere. Similary, the precipitation and the local circulation will have to be distributed by regional conditions in the final interpretation.

[1] A possible cause of the earth's magnetism, W. Sutherland, Terr. Mag. June, 1900; September, 1900; December, 1904.

This will reconcile much data that are apparently in conflict as evidence regarding the existence of synchronism generally.

(2) The discovery of ionization in the gases of the atmosphere, generated probably by the short-wave radiation, and the determination of the several types of the temperature waves in the lower strata of the atmosphere, lifts the veil from the problems of the diurnal barometric waves, the electric potential gradient, and the rate of change in the electric charges. These seem to be direct consequences of the temperature acting upon the density of the air in the different strata, and upon the locality, whether warm or cold, sought out by the ions.

(3) The cause of the *hourly* variation of the magnetic field is plainly shown to reside in the movements of the ions from one level to another. The cause of the *daily* variation of the magnetic field is probably in large part due to the movement of the ions from one hemisphere to the other, which at the same time produce the auroral displays simultaneously in each hemisphere, and the electric earth currents as local effects in the several portions of the circuit. This change of view relieves us of the difficulty of making the sun the source of all the energy displayed in a large magnetic storm, since the initial impulse is due to that portion of the energy disturbing the normal terrestrial equilibrium, while much of the observed effect is due to the motion of the ions in a closed terrestrial circuit. It remains to discover in what proportion the energy should be distributed among these three sources, the polar magnetic field of the sun, the variable radiant energy, and the terrestrial ionic circuit.

(4) It is now apparent that in using, for the basis of my original research, the magnetic field of the earth as a register or solar pulse recorder, I have been amply justified in tracing out through it as the intermediary the synchronism between the solar surface variations, shown by the spots, faculæ, and prominences, and the temperature and pressure effects at the earth, because it is in fact an intermediate effect, and evidently the most sensitive one with which we have to deal. The subtile influences of the invisible solar radiation may be registered in several ways, as bolometric spectrum curves, as actinometer integrations, as visible energy spectra, or they may be recorded as elastic potential effects and as magnetic force vectors. The latter are the most persistent in all kinds of weather, and most available for continuous observations. It is only necessary to determine what the connecting functions are in terms of magnetic force, to infer from the magnetic intensity what are the temperatures within two miles of the ground, in the midst of the cyclonic actions, to estimate the movement of the ionic currents, and to determine the relative amount of the incoming solar radiation, and thence to learn much regarding the variable nature of the circulation within the rotating mass of the sun.

(5) It is now easy to see that several lines of scientific inquiry as to the period of the solar rotation have been misdirected. The attempt to associate magnetic storms with the solar spots has failed, because the effective surface radiation on a given meridian of the sun may or may not be associated with a large spot, which clearly depends upon the internal circulation for its existence. Besides this, the magnetic storm is in part dependent upon distinctly terrestrial conditions. The application of Schuster's periodogram to the magnetic declination, in order to determine the periodicity of the solar residuals, was incorrect for this reason. While the magnetic declination varies with the season of the year, and from one year to another, as a consequence of the solar radiation, this component is really a term in the hourly vectors only, due to the vertical rise and fall of the ions from one stratum to the other. On the other hand the horizontal and the vertical components are the only ones which the terrestrial ionic circuits between the two poles will affect, while the declination is wholly subordinate. The rotation of the sun on its axis will in any event, whether the energy is transported in the oval polar circuit or as a linear radial radiation, not much influence the declination from day to day. It was a misapplication to assert that negative results of the periodogram carry with them a decisive critical meaning regarding any solar period. This tendency to mix up terrestrial and solar data in the same mass of numerical quantities, has been also found in the count of the number of the solar prominences, and is no doubt to some extent unavoidable since in our common observations we are not readily able to distinguish between them, but it is my opinion that in the present stage of the science it is better to employ a simple comparison of the data as they stand for the discovery of synchronism and periodicity, rather than to bury the several impulses in one massive computation. What is at present urgently required in this research, is to bring together all the data in simple homogeneous series, as in a carefully constructed ephemeris, for each of the several elements of the entire problem, determine what is solar and what terrestrial, and then introduce terms in the functions which will give some chance of separating the unknowns in a satisfactory analysis. This result will best be reached by intelligent cooperation, and I have no doubt that practical methods may be devised by means of which this purpose can be accomplished. It seems to me a very important advance to have gained a general view from which to correlate and harmonize so many of the problems that have heretofore been insoluble. It will, in conclusion, be proper to give some account of the instrumental apparatus available for the future progress of the research, and to add after that a brief description of the Mount Weather Observatory.

THE GENERAL ORGANIZATION OF THE RESEARCH OBSERVATORY.

In organizing the work of an observatory appropriate to this research it is evident that the demands of meteorology in the United States naturally divide its activities into two classes.

(*a*) The first pertains to education and miscellaneous minor problems, and the second to the solar-terrestrial meteorology whose object is to advance the possibilities of daily and seasonal forecasts. The ordinary collegiate instruction in meteorology will probably be limited to climatology and elementary principles in general meteorology, until a practical application for such knowledge can be found outside the activities of the Government service. The great expense of collecting numerous simultaneous observations will no doubt preclude commercial enterprises in that direction, so that forecasting in the United States will always be confined to the U. S. Weather Bureau. In large manufacturing plants a knowledge of weather conditions is becoming more essential to successful business, so that a demand is likely to arise for well trained men in that direction. For our own service the exigencies of modern science are rapidly outgrowing the capacity of men unskilled in mathematics and physics to keep up with the advanced problems, and it is necessary for the Government to undertake the training of its own experts in the higher meteorology. The time is not far distant when each large city will require the presence of a skilled scientist in connection with the local office, especially as the universities are inclined to cooperate in the way of lectureships in connection with the courses of instruction in physics and geology. It is hoped that at Mount Weather the resident students may be employed as assistants in the various lines of work, and that an immediate contact with the highest lines of research to be inaugurated will make them understand and appreciate the requirements of physical research work. A good physical laboratory is to be constructed, the purpose of which is to afford an opportunity to train men in research methods, and to investigate the numerous problems arising in meteorology.

(*b*) The second division of the work embraces the operations of the solar physics observatory, the magnetic observatory, the balloon and kite plant, and should be operated as a unit, because the cosmical problem has branches in each of these realms of physics, and they can not be separated without injuring the progress that is to be expected from their cooperation. The primary policy of this investigation is to be determined by the fact that the energy effective in producing weather of short periods and climate of long periods, consists of solar terms and terrestrial terms, which are very closely interwoven, but must be separated from each other. In the process of disentangling the solar and terrestrial terms, respectively, the functions connecting the several phenomena, or the physical relations between them, must be carefully studied. At present the entire subject is in confusion, and no deliberate attempt can be made to work up the relative values of the several forces until the observations of the several kinds are placed side by side for comparison. The establishment of suitable series of homogeneous observations in the several branches is the first work of such an observatory. We have so recently become convinced that there is a genuine solar-terrestrial problem for the meteorologist to investigate, that but little definite has been done in putting such a comparative work in operation.

The numerous contributions to the general subject from all portions of the world are absolutely bewildering in their complexity, and we can not expect to make any serious advances unless the details of such observations can be classified in one far-reaching, comprehensive scheme. The observatory must be organized like an army, with a general supported by officers who will execute the several parts of the operations required in the plan of campaign. I shall attempt merely to enumerate, in the next paper, the instrumental methods that it is proposed to employ at Mount Weather, so far as experience shall prove them to be practicable. Every stage of the instrumental work, and that of the reduction of the observations, will imply that first-class training is required, and of course the actual success of the enterprise will depend almost entirely upon the number of expert scientists that can be procured for such a service. As stated above, the margin is not large upon which we can do the solar work, owing to the diminished effects at the earth of the sun's variations, due to its great distance from the earth, and we must waste nothing by using bad methods of work and unskilled men, if any profitable result is to be secured. Poor workmanship and untrained men are barred by reason of the rigorous scientific demands that are placed upon these operations by the natural physical conditions which prevail in cosmical meteorology.

## NOTES AND EXTRACTS.

### KITE WORK IN THE ATLANTIC TRADE WIND REGION.

Under date of September 7, 1905, Prof. Dr. H. Hergesell writes that he has just returned from a scientific expedition for the exploration of the upper atmosphere over the Atlantic Ocean, and adds:

I have just received the MONTHLY WEATHER REVIEW for May, and find on page 209 an interesting communication from Mr. Rotch. In one place he says: 'The trade winds and doldrums will thus be traversed and it is hoped that the meteorological conditions prevailing above them, which are practically unknown, will be at least partially revealed.'

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From this it would appear as though in general no kite ascensions had been made in the trade wind regions, whereas in the region between Gibraltar, the Canaries, and the Azores, at my request, a series of kite ascensions have been made by the Prince of Monaco, extending up to an altitude of 4500 meters. I have published the results in the Comptes Rendus of the Academy of Science of Paris, and I send a copy herewith and pray that if possible you will publish at least a summary in your periodical.

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'In the spring of 1904 the Prince of Monaco undertook to devote his private yacht to the study of the meteorological conditions prevailing in the atmosphere above the ocean. Prof. Dr. H. Hergesell was associated with him in this work. Hargrave kites were used having respectively 3 and 5.7 square meters of surface. The kite lines were steel wire of 0.7 and 1.0 millimeter diameter. Eight kite ascensions were made above the Mediterranean between April 12 and 24, 1904, at the beginning of the cruise, sixteen above the Atlantic, and one above the Baltic. The maximum altitude of 4510 meters was attained on the 9th of August to the northwest of the Canaries and a nearly equal altitude of 4360 meters on the 28th of August to the south of the Azores. Many other ascensions exceeded 2000 meters. The ascensions above the Mediterranean gave this general result, that at the free surface of the water there is a very rapid diminution of temperature and that the wind diminished very much with altitude. However, on the coast of Corsica with a southeast wind we found a warm current blowing from Corsica and the temperature increased with altitude, while at the same time the humidity diminished; at an altitude of a few hundred meters there was a calm. These exceptional conditions seem to be due to the influence of the neighboring coast.

'The ascensions made over the Atlantic Ocean had for their special object the exploration of meteorological conditions in the trade wind region. They began July 19, 1904, on the Portuguese coast opposite Oporto. The yacht sailed toward the Canaries which were doubled and then toward the Azores whence it returned to the Mediterranean. Throughout the whole region we made kite ascensions at convenient intervals, the last one being on September 20, 1904, with the following principal results:

'We found the trade wind blowing from the northeast in the latitude of Oporto at an altitude of 400 meters, but at the level of the sea the wind was northwest. Beginning with the latitude of Lisbon the trades were also observed in the lowest stratum as a feeble wind from the northeast. In proportion as we advanced toward the Canaries this northeast wind increased in force. From 35° north to the Canaries we observed a steady wind of seven meters per second. Farther south the velocities attained even nineteen meters per second, but only in the neighborhood of the islands. The results of all the ascensions made in this trade wind region were sufficiently concordant to permit of the following résumé:

'In the lower layers of air there is a strong diminution of temperature with altitude; the adiabatic gradient 1° per 100 meters is always attained. In the lowest stratum it is even exceeded. The thickness of this adiabatic layer varies between a 100 and 600 meters. The relative humidity which is 70 or 80 per cent at sea level increases gradually to 95 or 100 within this stratum. At the upper limit of the layer there is a sudden change, the temperature suddenly rises many degrees and the humidity suddenly diminishes to values lower than 50 per cent. After this sudden change there comes a layer of inversion or of mixture that attains sometimes a thickness of 1000 meters where the temperature continues to rise and where the humidity diminishes to 10 or 20 per cent. In this layer sometimes at an altitude of 1000 meters we find temperatures as high as 30° C., while at sea level we have only 22° or 23° C. Above the layer of mixture we find again a layer having an exactly adiabatic gradient, but in which the humidity is small, contrary to the conditions in the first adiabatic layer. However, the relative humidity increases with altitude in such a way that the hygrometric richness[1] remains constant. This permits us to conclude that the current must be descending and I will call this zone the layer of antitrade. According to our observations it attains an altitude of at least 4500 meters and probably extends much higher.

'It has been possible to determine the direction of the wind at different altitudes and even to measure the velocity by both direct and indirect methods. In the first adiabatic layer we find a trade wind from the northeast of about seven meters per second. As the height increases the wind gradually backs more frequently from north to northwest, but in two cases veered from northeast through east to southeast and south. At the inversion altitude, that is to say about 600 meters, the direction changes sometimes suddenly, and the force diminishes considerably. The layer of the trade, properly so-called, is therefore quite shallow. A current from the southwest that should correspond to the theoretical antitrade has never yet been found by kite ascensions, although these have oftentimes exceeded the altitude of the peak of Teneriffe. Many corroborating circumstances have forced me to think that the southwest winds (antitrades) observed on the peak of Teneriffe by many observers have a local origin and are due to the influence of the island.

[1] The richesse hygrometrique or hygrometric richness is a term introduced into French meteorology by Jamin about 1880, it is a ratio computed by dividing the actual vapor tension by the barometric pressure less the vapor tension, and multiplying by the constant 0.623. In other words it is the ratio of the weight of the vapor to the weight of the dry air and is very nearly identical with the so-called specific humidity which is the weight of the vapor contained in a kilogram of moist air.—[ED.]